Determination of a High Resolution Paleoearthquake Chronology for the Northern San Andreas Fault at the Vedanta Marsh Site, Marin County, CA (Renewal)

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Element II: NEHRP research priorities to understand earthquake occurrence and effect

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Introduction:

The main objective of this NEHRP research is to obtain a high-resolution chronology of paleoearthquakes on the 1906 rupture trace of the San Andreas fault and to determine slip-per-event of pre-1906 earthquakes through detailed three-dimensional excavations. Determining the timing of past San Andreas fault earthquakes has great significance for the long-term seismic hazards of the densely populated San Francisco Bay region. The results of this research will be used to test earthquake rupture models of the San Andreas fault and to improve the earthquake probability estimates published by the U.S. Geological Survey. The anticipated outcome of this research will be a better definition of the earthquake cycle in the San Francisco Bay area.

This research is being conducted at the Vedanta paleoseismic field site in Olema, Marin County, CA. The Vedanta site has all of the elements that promise to provide a high-resolution paleoearthquake chronology for the past 3000+ years. The fault zone is wide with multiple fractures and definable event stratigraphy. The layers contain *in situ* organic material that will provide age control. The margins of channel deposits, downed Douglas fir trees, and the margins

of landslide debris lobes detected in trench exposures can provide piercing points to match across the fault in order to determine paleo-slip. To clearly define the timing and slip of past earthquakes, we need redundancy in the observable and collectible data. Previous trenching investigations conducted at Vedanta site in 2001 and 2002 have yielded abundant data including marsh stratigraphy classification, earthquake event evidence, and radiocarbon dating. Following is a summary of research conducted during the 2004 field season in which 3-D excavations recovered an offset paleochannel that documents a cumulative coseismic displacement around 8 meters during the last two earthquakes: 1906 and the penultimate event.

Investigation undertaken:

Previous trench investigations revealed a paleochannel cut by the northern San Andreas Fault in Trench 4 (Figure 1). During the 2-month 2004 field season, 3-D excavations were conducted carefully on both side of the Trench 4 along the fault trace in order to accurately document the cumulative coseimic displacement of the offset paleochannel.

Two larger pits were dug mainly by hand to depths around 1.5 m and a width of 2 to 4 m (Figure 2). The excavations were done progressively to uncover the buried channel, and to leave the channel deposits intact. The stratigraphy exposed in the pit floors was mapped on a grid and photographed. Pit exposures were logged on both graph paper and photo mosaics. Radiocarbon and soil samples were collected from key stratigraphic horizons.

We also excavated a trench on Olema Ridge at a location along the 1906 San Francisco earthquake rupture photographed by G.K. Gilbert immediately after the earthquake (Plate 48-A, Lawson report). The main objectives of this trench were to 1) document the fault scarp degradation since 1906, 2) map the subsurface evidences of the 1906 earthquake and compare it to the surface morphology, and 3) possibly determine older earthquake faulting events.

In collaboration with Robert Kayen from the U.S. Geological Survey and David M. Doolin from the Department of Civil and Environmental Engineering, University of California at Berkeley, we conducted LiDAR surveys of the San Andreas fault at the Vedanta and Olema Ridge paleoseismic trench sites, We experimented with collecting tripod LiDAR (Light Detection And Ranging) data in order to test its utility in stratigraphic and tectonic geomorphic mapping. To characterized the terrain surface surroundings and within the exposed trench walls, we performed ground-based LiDAR surveys using a portable color sensitive tripod-mounted system.

At the end of the 2004 field season, a trench party was held at the Vedanta and Olema Ridge trench sites. Over 30 researchers and employees from the USGS, the National Park Service, and other agencies, organizations, and corporations came to the trench sites and gave their comments.

Preliminary results of the 2004 field season will be presented at the 2004 AGU Fall Meeting in San Francisco, CA.

Results:

The excavations at Vedanta paleoseismic site exposed a 3-m-wide paleochannel that has been offset right-laterally 7.8-8.3 m by coseismic slip during the past two large earthquakes: 1906 and the penultimate earthquake. The paleochannel was eroded into a silty clay marsh deposit and was filled after AD 1400. Both the silty clay layer and the paleochannel deposit are directly overlain by an in situ burn/peat sequence. The penultimate earthquake occurred while the peat was at the ground surface whereas faulting from the 1906 earthquake terminates within an overlying gravel/fill sequence. Preliminary OxCal analyses of radiocarbon dates indicate that the penultimate earthquake occurred in the late 17th to early 18th century.

In plan view, two main fault traces were mapped in the excavation. The northwestern portion of the paleochannel is offset across a single fault trace. Just southeast of this portion of the channel the fault splits into two traces. We believe that one of these traces likely slipped only during 1906 and the other trace slipped during the penultimate earthquake. Unfortunately, the overlying stratigraphic section that could resolve the exact reconstruction of movement on these faults is missing due to the excavation of an artificial drainage ditch at this location in the 1940's. Matching the north margin of the paleochannel to the first exposure of gravel in the zone between the two fault traces gives an offset of 5 m. We have historic records that show the 1906 coseismic slip near the study site was about 5m from field notes of David Starr Jordan (Stanford University Archives) who describes two 16 ft (5m) offsets: one of a tree located about 150m SE of the offset channel and the other of a path to the Shafter barn located about 300m NW. As the locations of these two historical records are so close to the study site, it is reasonable to assume that our excavation site has the same amount of coseismic slip in 1906.

Our data indicate that the paleochannel was offset about 2.8 to 3.3 m during the penultimate earthquake which occurred in the late 17th to early 18th century, and that the San Andreas fault along this segment is capable of slip in earthquakes smaller than 1906.

Non-technical Summary:

Three-dimensional excavations along the 1906 trace of the northern San Andreas fault at the Vedanta marsh paleoseismic site near Olema, CA have yielded new data on the timing and amount of slip during the penultimate earthquake on this fault section. A buried channel has been cumulatively offset along the fault trace about 8 m during the last two earthquakes: 1906 and the penultimate. Historical records of surface displacements on the San Andreas fault very close to this location indicate 5 m of slip from the 1906 San Francisco earthquake. If we assume 5 m of 1906 slip occurred at the Vedanta site, then coseismic slip of the penultimate earthquake was around 3 m. These data suggest that the penultimate earthquake that is constrained by radiocarbon data to have occurred in the late 17th to early 18th century may have had a smaller magnitude than the 1906 earthquake.

Reports published:

Preliminary research results will be presented in the 2004 AGU Fall Meeting in San Francisco.

- Niemi, T. M., Kayen R., Zhang, H., Dunn C.R., Doolin D.M., 2004, LiDAR Imagery of the San Andreas Fault Zone at the Vedanta and Olema Ridge Paleoseismic Trench Sites, Pt. Reyes, CA (abst.): Eos Trans. AGU, 85(47), Fall Meet. Suppl., Abstract G13B-0811, San Francisco, CA.
- Zhang, H., Niemi, T. M., Allison A. and Fumal, T. E., 2004, Noncharacteristic slip on the northern San Andreas fault at the Vedanta marsh, Marin County, CA (abst.): Eos Trans. AGU, 85(47), Fall Meet. Suppl., Abstract T13C-1395, San Francisco, CA.

*American Geophysical Union (AGU)

Availability of processed data:

Trench logs are available in Adobe PhotoShop CS and Adobe Illustrator CS format, or in Adobe Acrobat PDF format. Carbon-14 data is in Word 97 or Excel 97 format. Contact Dr. Niemi for further information: NIEMI, Tina M., Department of Geosciences, University of Missouri - Kansas City, 5100 Rockhill Rd., Kansas City, MO 64110, niemit@umkc.edu;

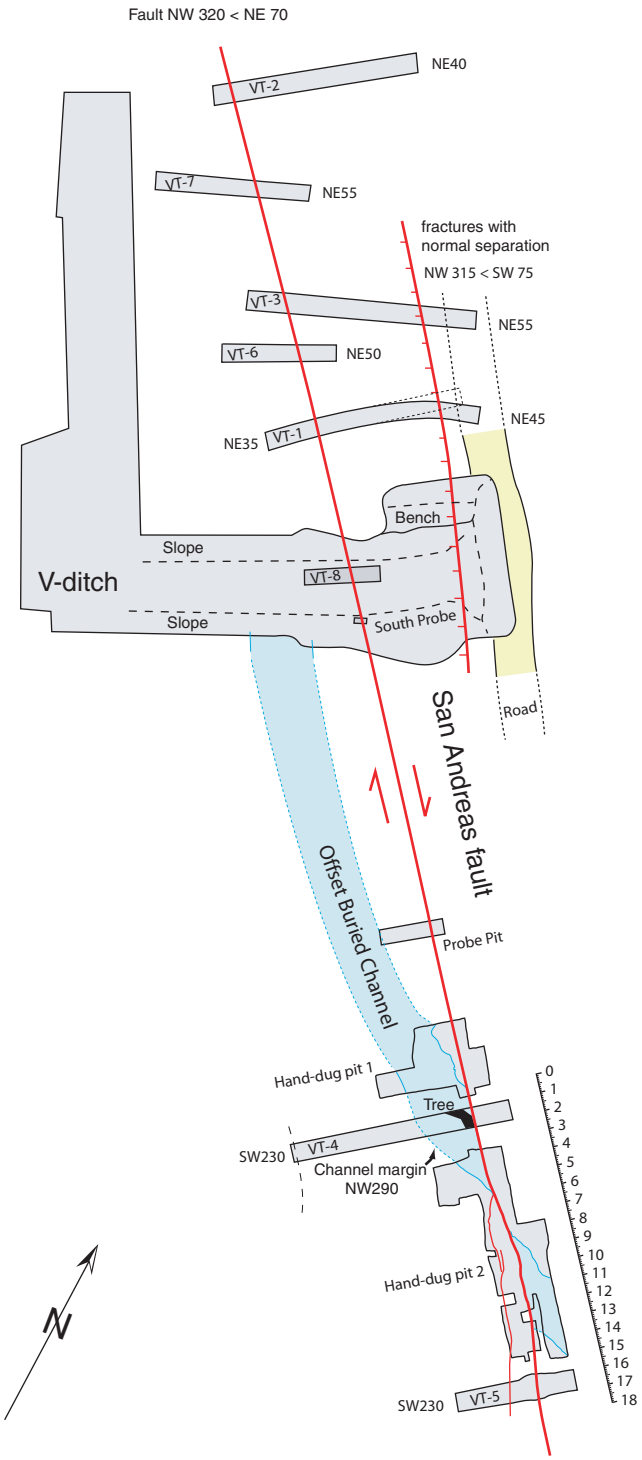

Figure 1, Map of trench locations at Vedanta marsh.

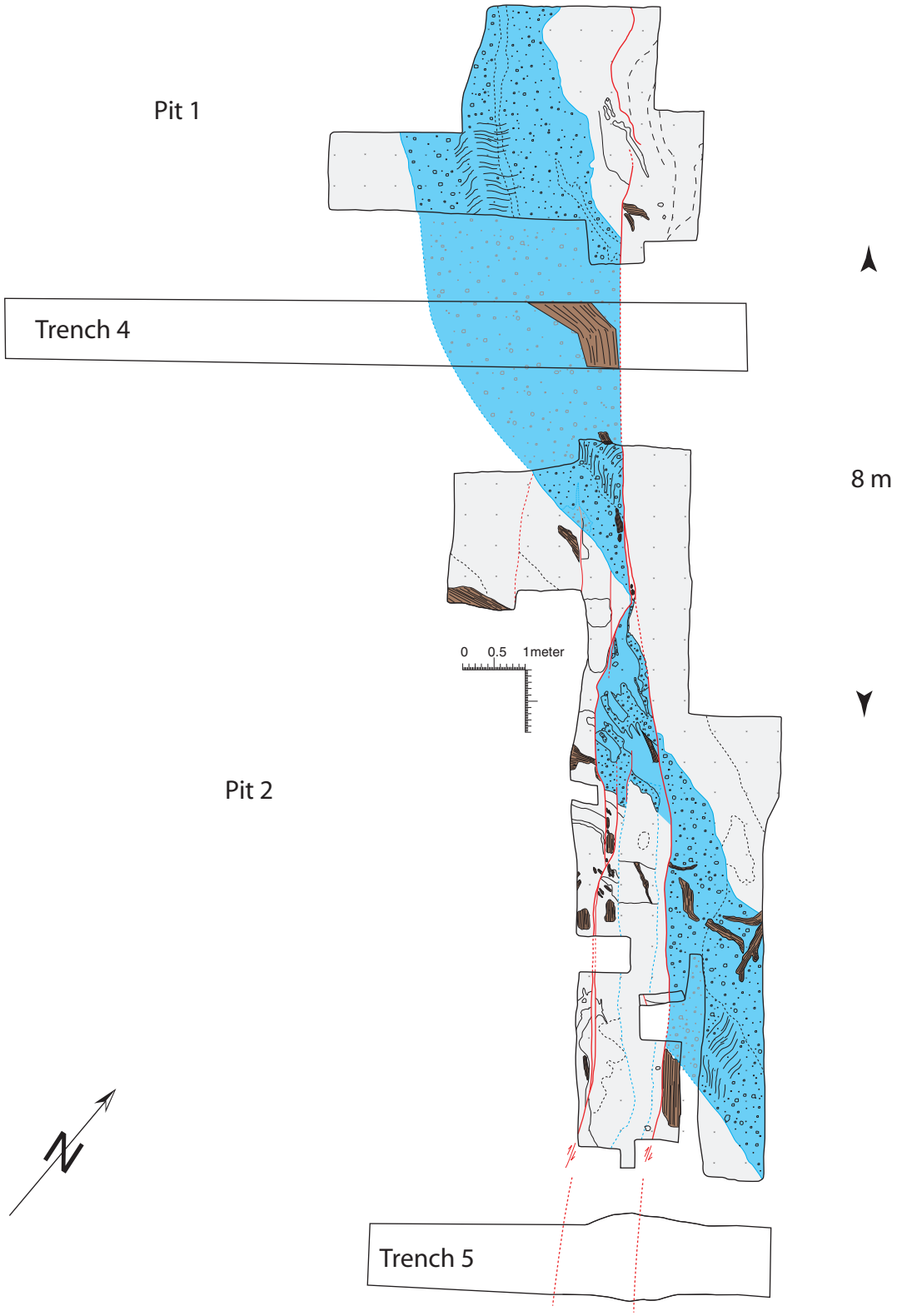

Figure 2, Simplized log of the offset paleochannel.